

# The effect of firn-aquifer drainage on the Greenland subglacial system

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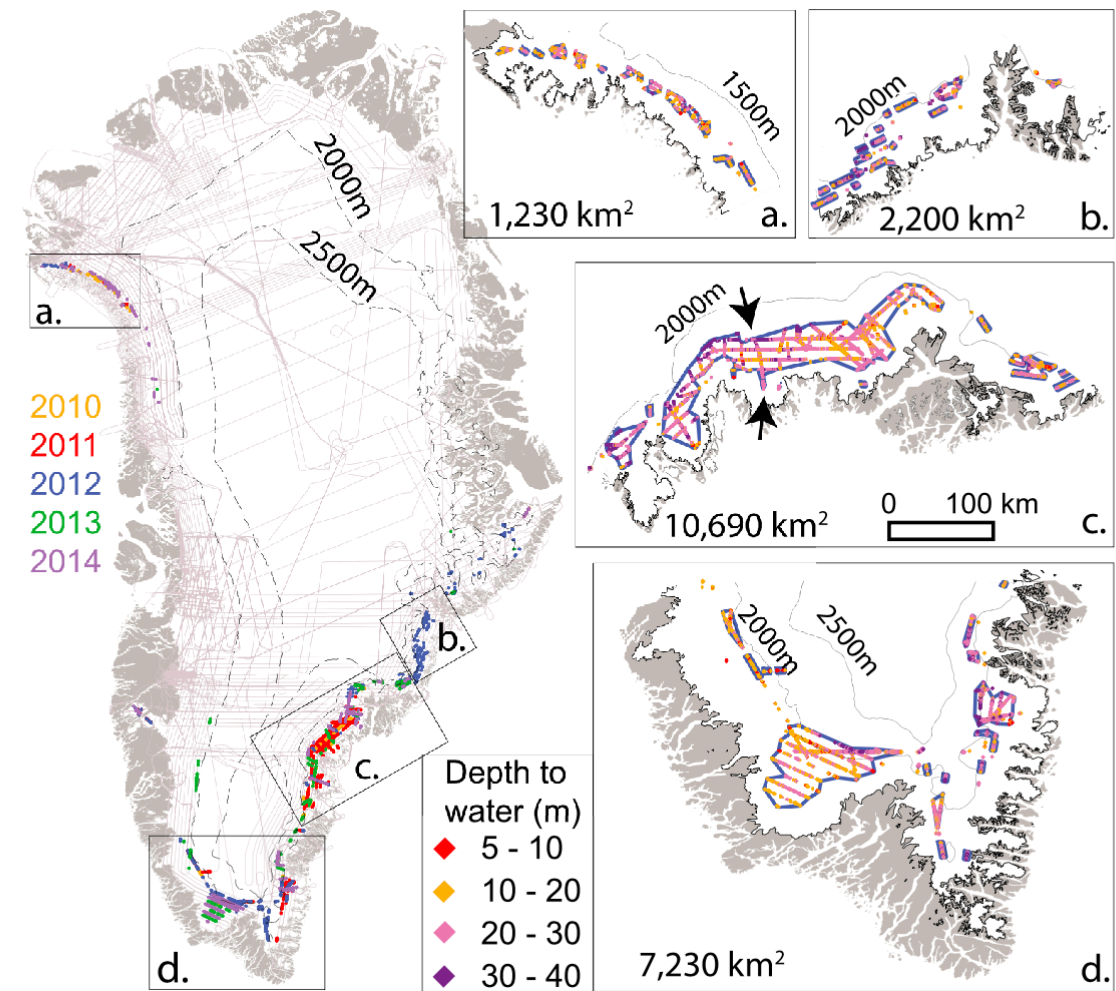
Subglacial efficiency and storage modified by the temporal pattern of high-elevation meltwater input

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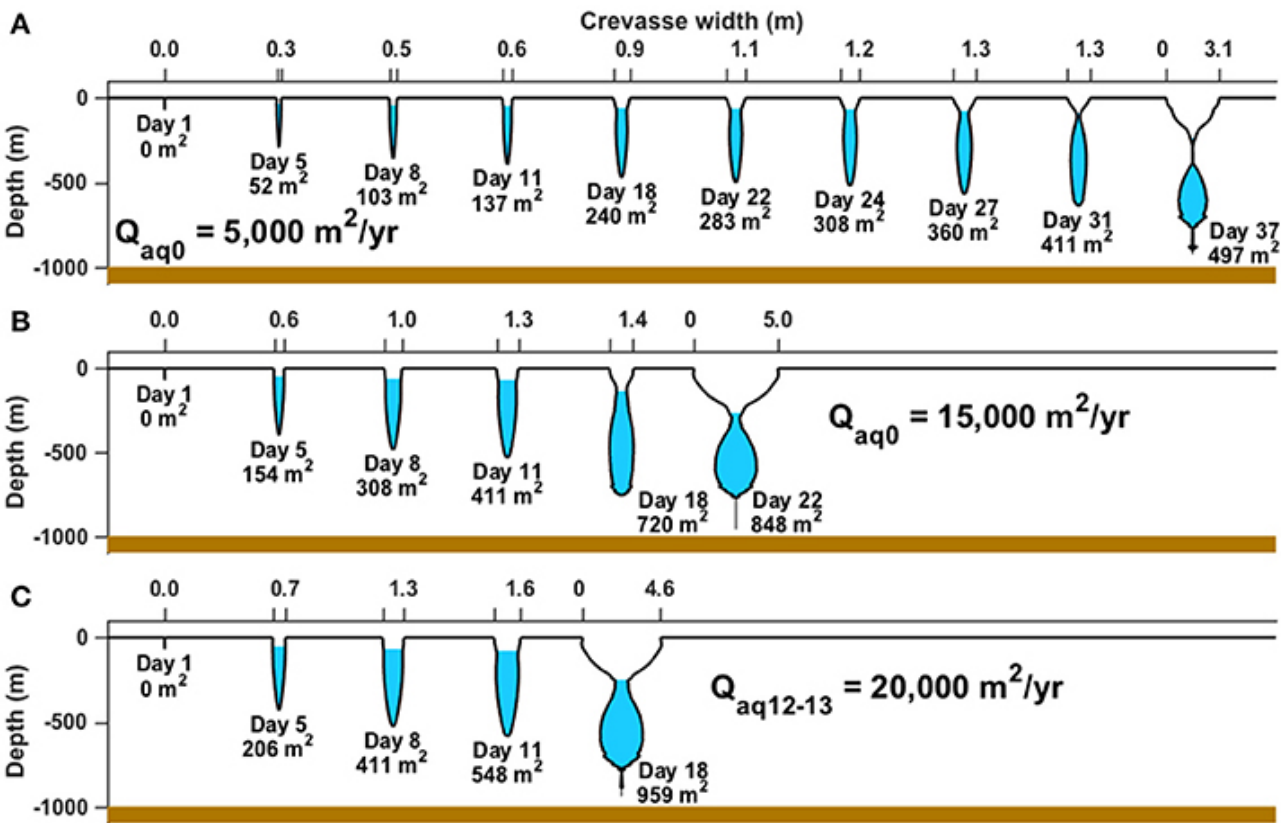


^ Contributed equally to this work.

# High elevation melt storage and release



Miège et al. (2016)



Poinar et al. (2016)

# High elevation melt and ice dynamics

Can firn aquifer release/drainage substantially alter a glacier's dynamic behavior?

- \* What is the temporal pattern of subglacial meltwater release from the firn aquifer?
- \* How does firn aquifer drainage alter the subglacial hydrologic system?

Subglacial release of firn-stored meltwater causes substantial changes in both subglacial pressure and subglacial channel persistence, despite being only ~10% of total meltwater input.



# Modeling outlet glacier subglacial hydrology

## \* Idealized outlet glacier domain

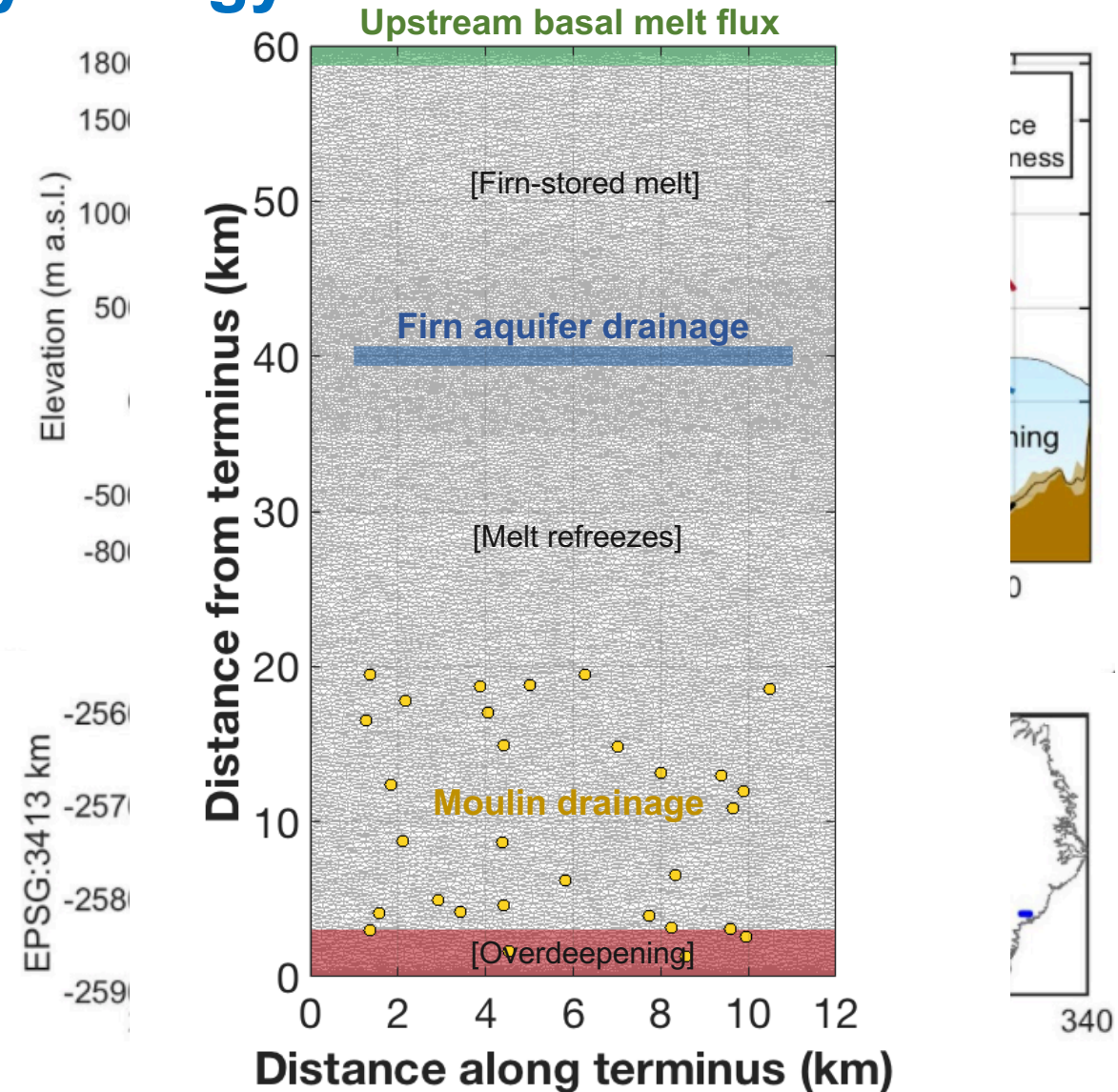
- Basal motion 90% of InSAR-derived velocities (Joughin et al., 2017); capped at  $500 \text{ m} \cdot \text{a}^{-1}$
- Effective pressure at terminus = 0
- No tidal effects, slight terminus overdeepening

## \* GlaDs subglacial model (Werder et al., 2013)

- Distributed and channelized drainage
- Spin-up without meltwater input
- 3-day time step, 5 year model runs

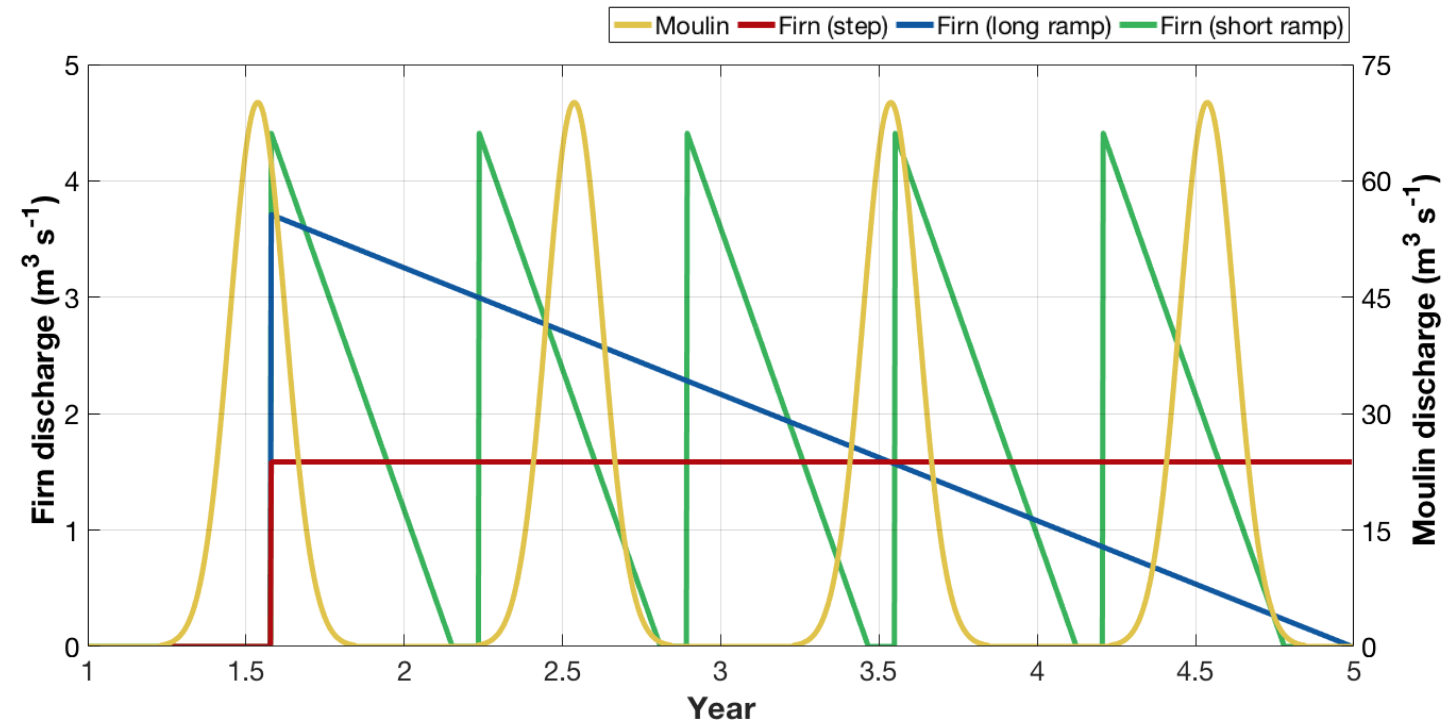
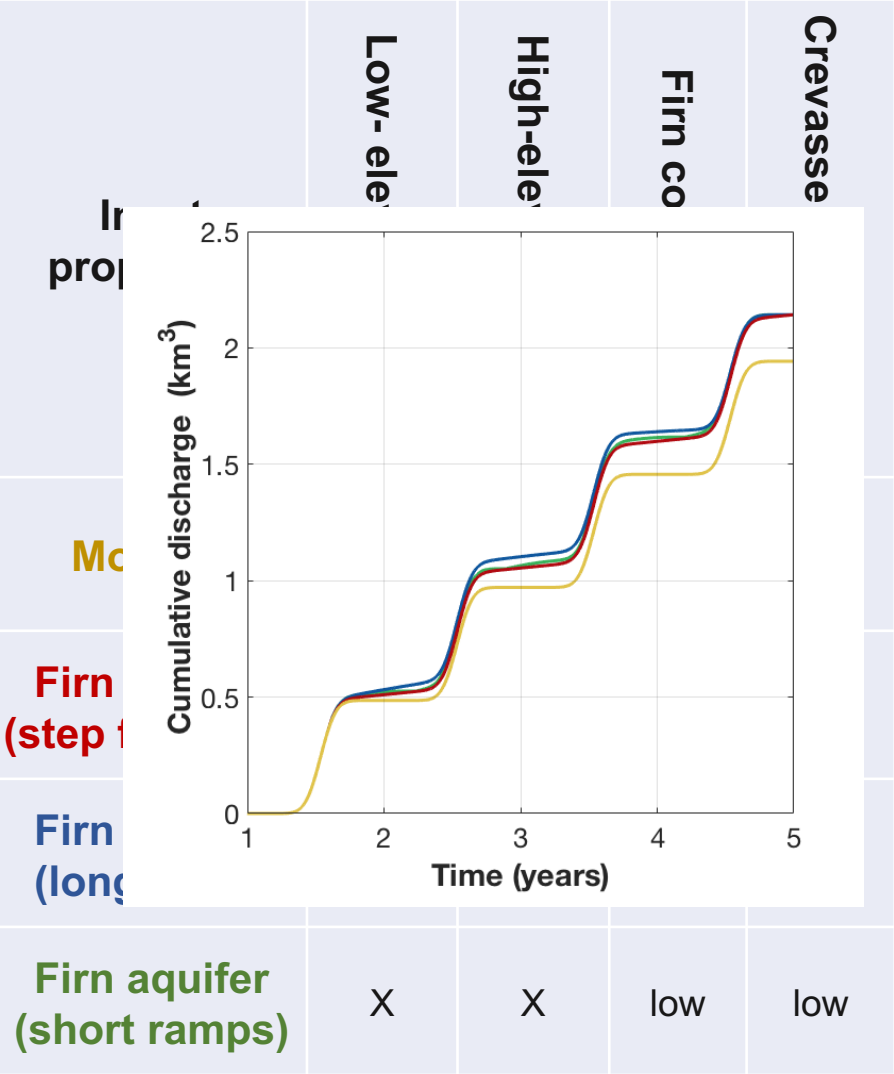
## \* Melt inputs from both moulin and firn sources

- Upstream flux due to accumulated basal melt
- Idealized seasonal inputs scaled to 1980-2016 MERRA-2 runoff values
- Varying firn aquifer inputs



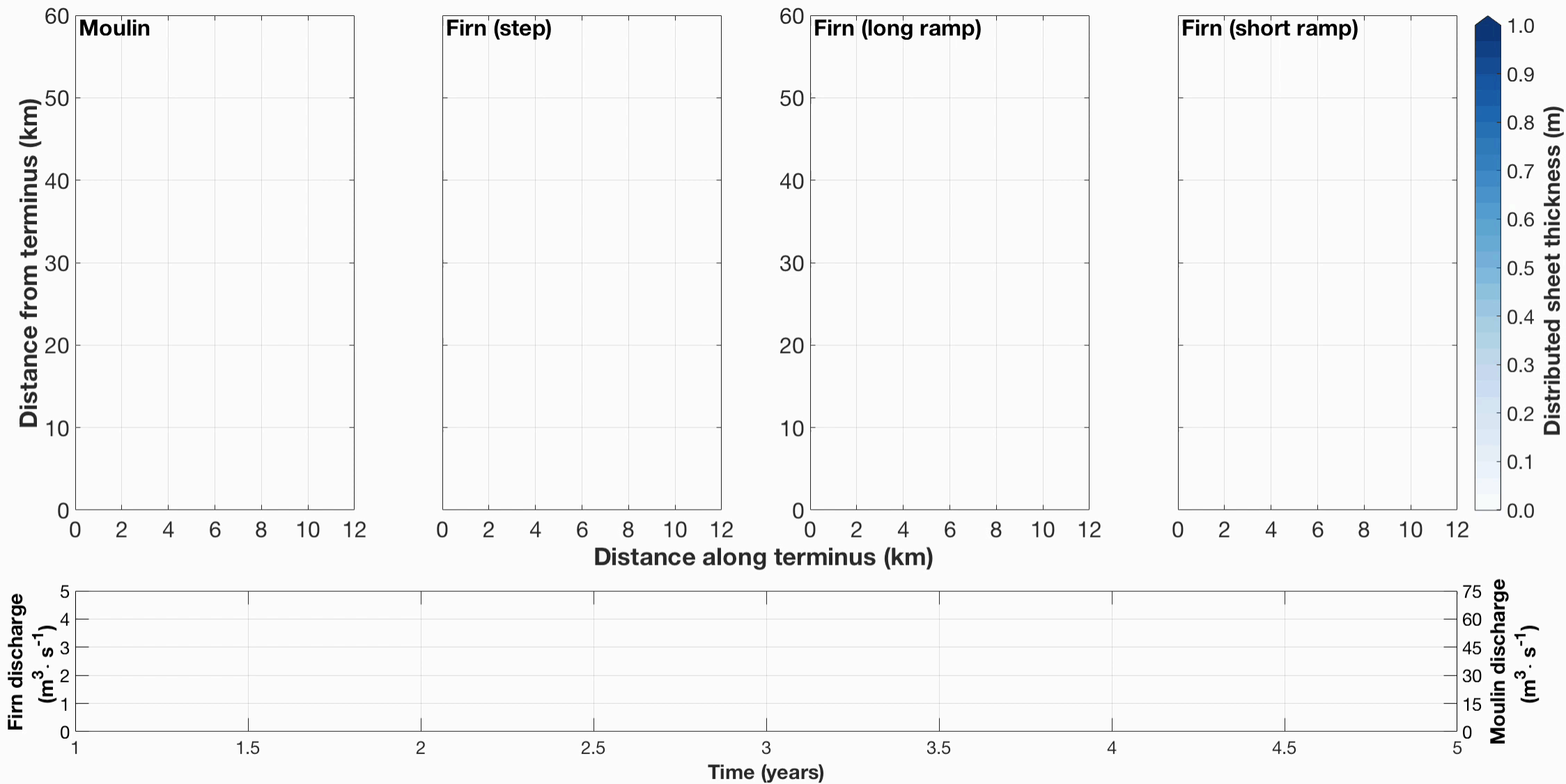


# What does firn meltwater release look like?





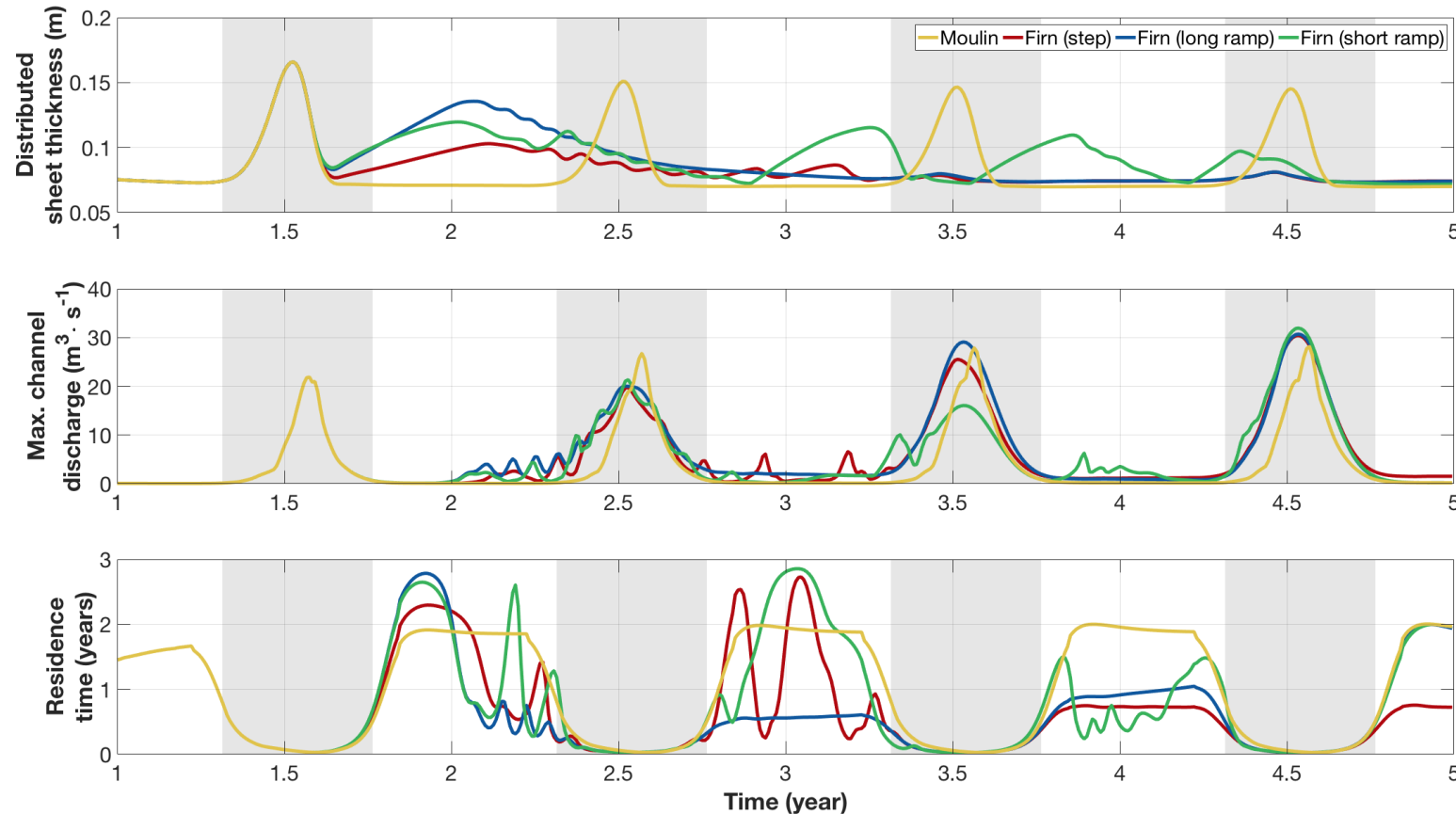
# Modeled water thickness and channel evolution



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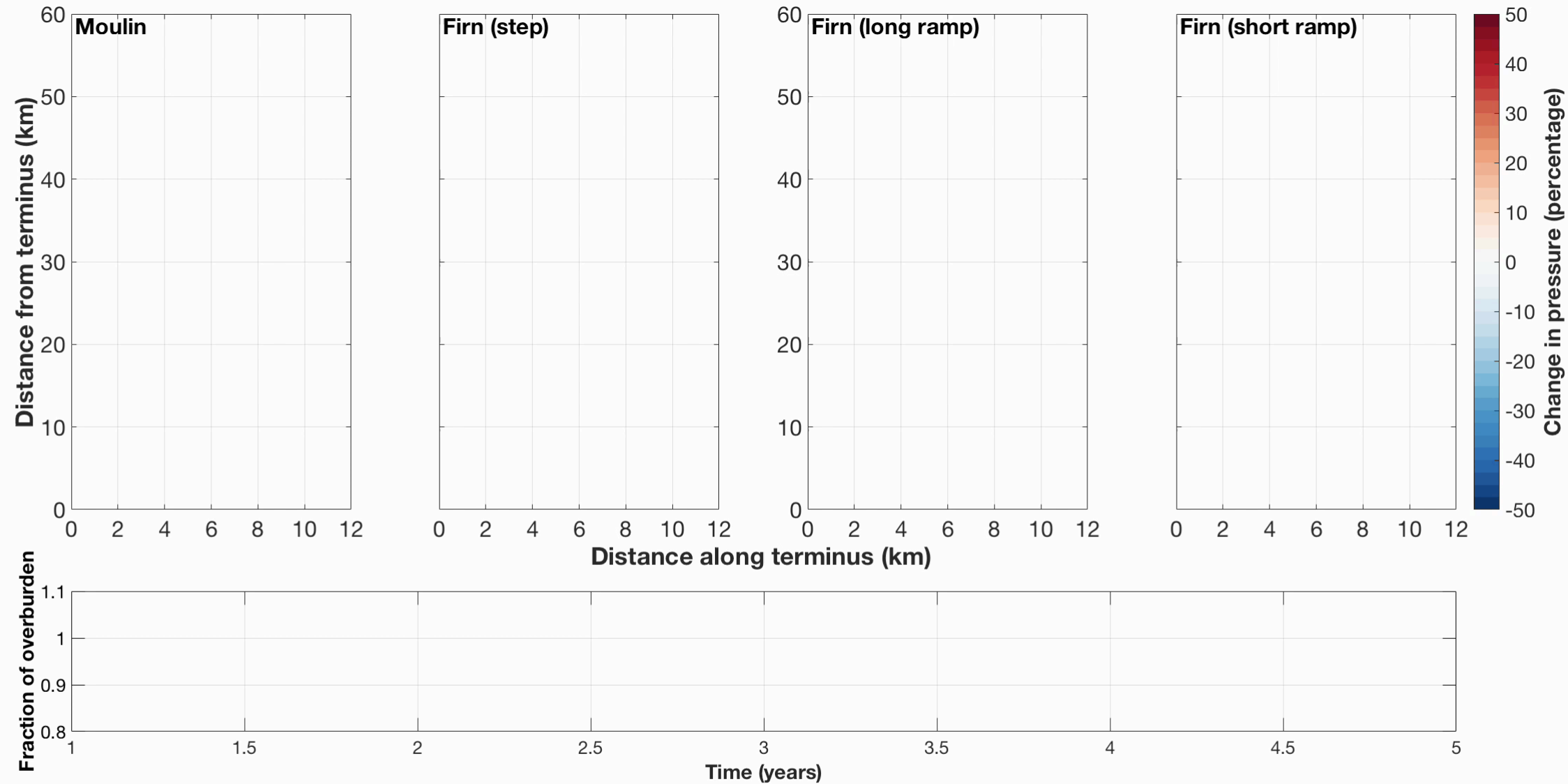
Firn inputs result in:

- \* Increased water storage within the distributed system.
- \* Dampened seasonal variations in sheet thickness.
- \* Increased channel growth and discharge during summers.
- \* Reduced residence time for subglacial meltwater.





# Changes in subglacial water pressure and channel persistence

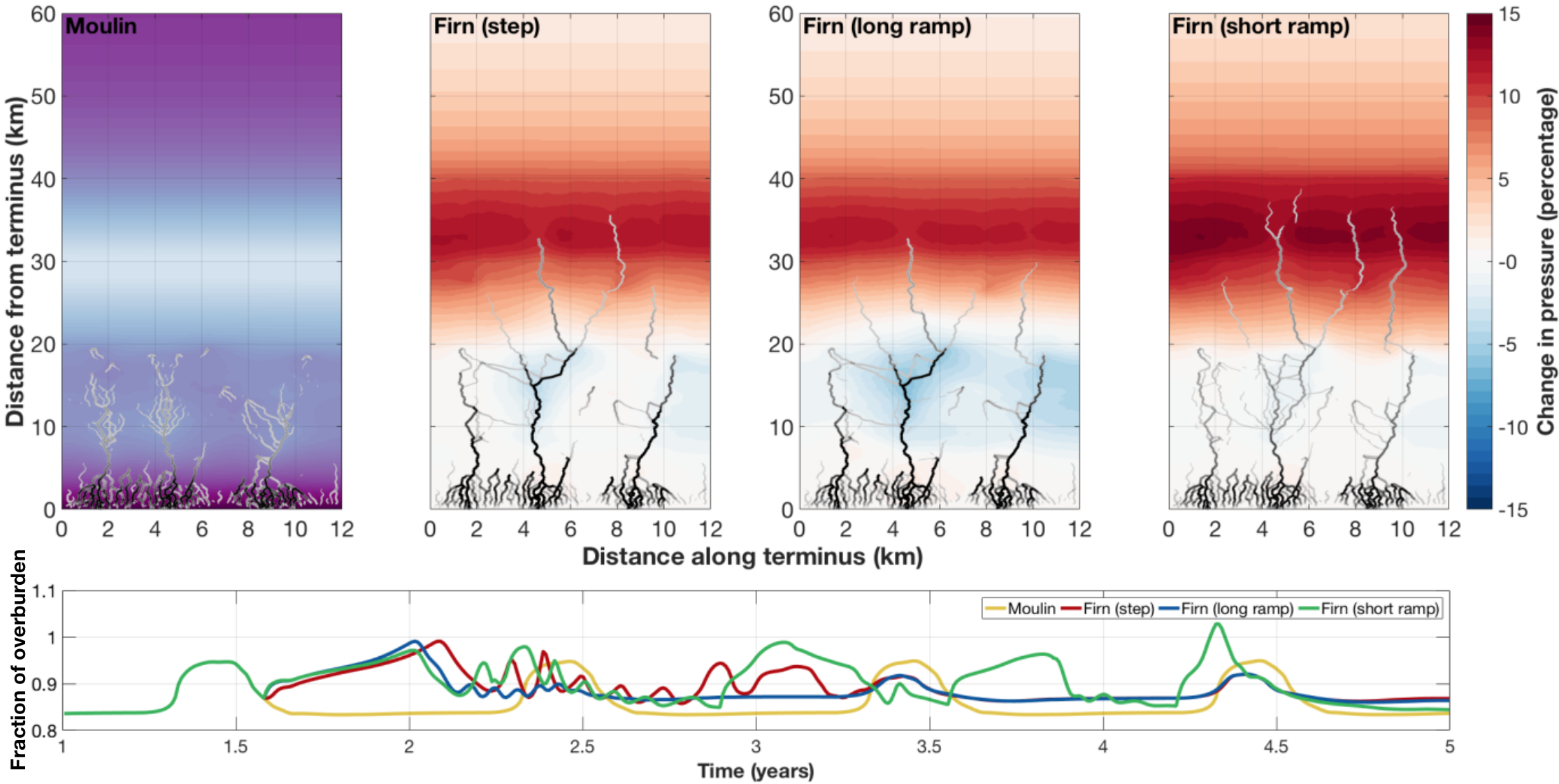






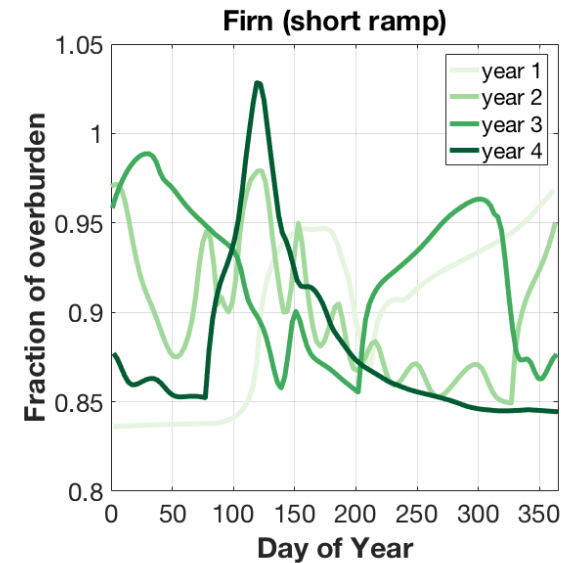
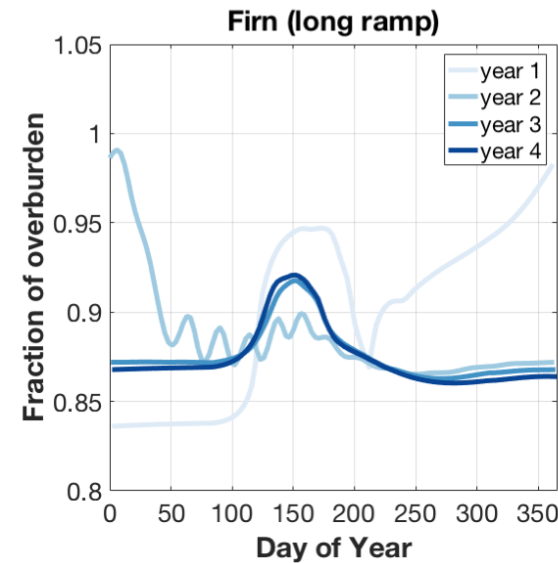
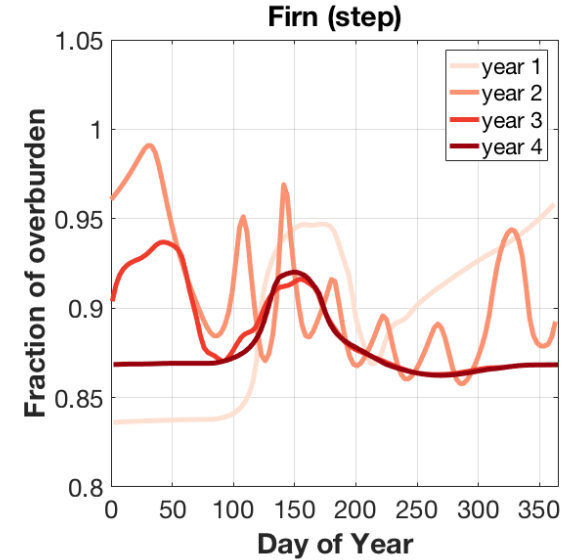
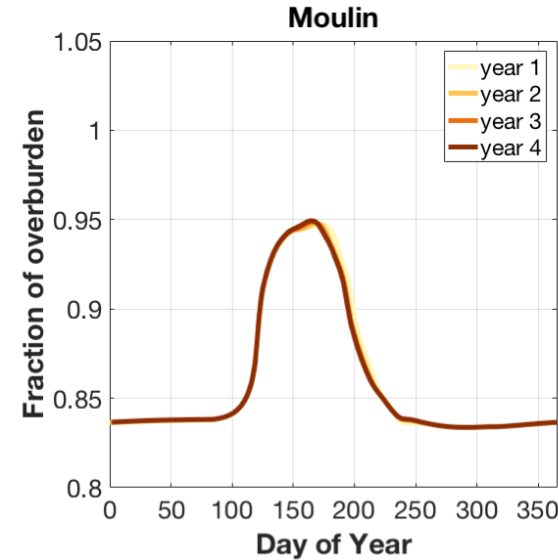
# High elevation melt storage and drainage

- $5 \leq p < 20\%$
- $20 \leq p < 40\%$
- $40 \leq p < 60\%$
- $60 \leq p < 80\%$
- $80 \leq p \leq 100\%$



# Subglacial behavior

- Increased pressures at high elevations, but decreased pressures in regions with seasonally fluctuating meltwater input.
- Persistent near-terminus subglacial channelization with constant firn inputs.
- Development of pressure waves, particularly with short ramps.
- Development of oscillatory subglacial drainage due to exchange between the distributed and channelized systems (e.g., Schoof et al., 2014)



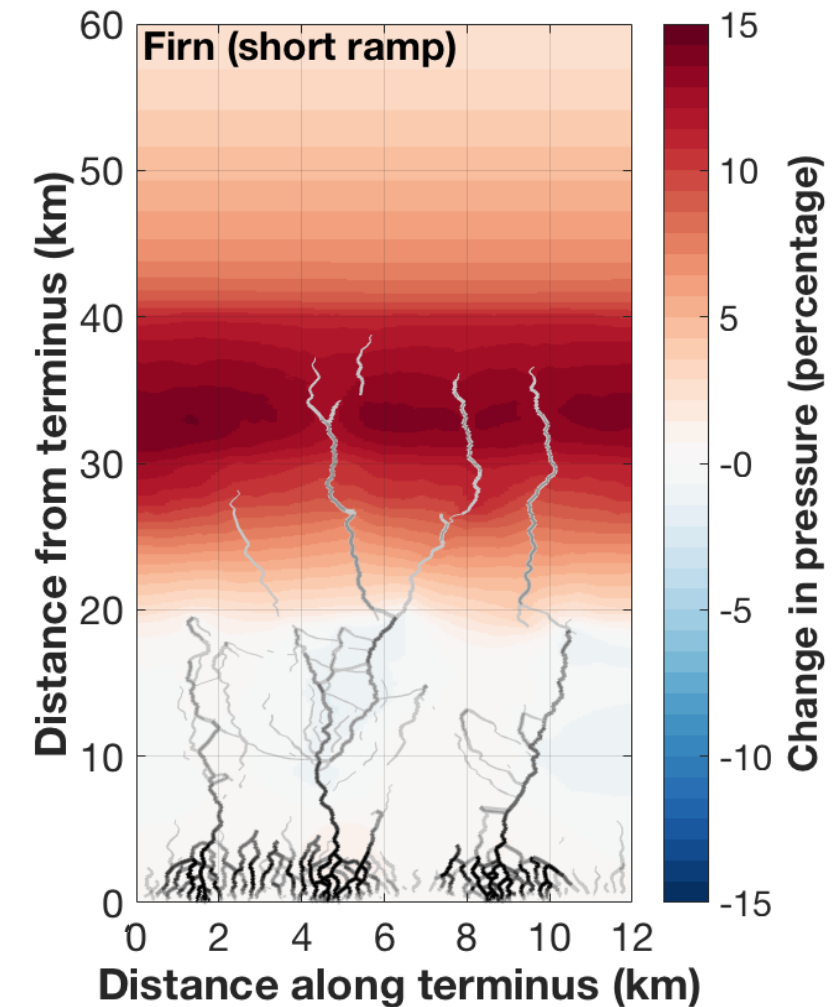
# Caveats to interpretation

## \* Bed conditions

- Outlet glacier beds tend to be weak (Shapiro et al., 2016) and likely sediment rich
- Lack of basal topography and the given moulin distribution
- Dampened ice velocities and lack of coupling could mask the importance of inefficient subglacial flow

## \* Water storage and release

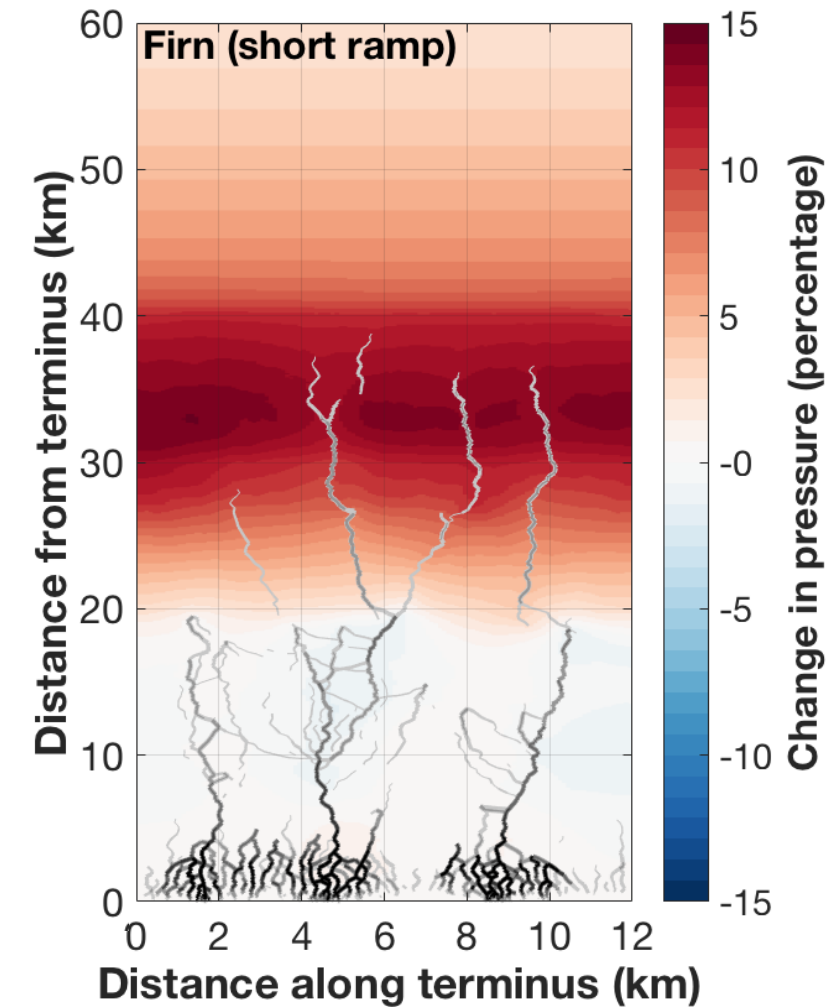
- Moulin inputs do not contain realistic spatial or temporal variability
- Firn inputs are poorly constrained, particularly sub-seasonally and are likely to be variable and at least somewhat correlated to the melt signal



# Conclusions and implications

## \* Impacts of firn aquifer drainage

- Firn inputs can result in increased subglacial pressures, which could cause spatially extensive velocity perturbations outside the summer melt season (e.g., Koenig et al., 2017, IGS Boulder)
- Pressure variations may also be due to the exchange of meltwater between the distributed and channelized system under constant melt inputs and may not signal the exact timing of the firn-subglacial connection
- Dampening of any moulin-driven seasonal signal (implications for seasonal melting and subglacial channelization in Antarctica)



# Conclusions and implications

## \* Impacts of firn aquifer drainage

- Under 'constant' firn inputs, we observe increased pressures at high elevations and reduced pressures at low elevations
  - Consistent with observed ice velocity behavior on land-terminating regions despite in the timing of melt delivery
  - Changes in regional driving stress (not sure if I want to mention this)
- Increased subglacial channel extent and persistence drives a reduction in low elevation subglacial pressures and potentially lower ice velocities over multiple years
  - Reduced terminus ice discharge can act to destabilize terminus position and help encourage outlet glacier retreat (e.g., Hewitt, 2017, EGU)

## \* Constrain both the timing of delivery and the long-term change in Greenland-wide firn aquifer extent

